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Mellquist et al.

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(54) **LOGICAL RACK CONTROLLER**

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H04L 49/00	(2022.01)
H04L 41/08	(2022.01)
H04L 45/02	(2022.01)
G06F 9/4401	(2018.01)

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CPC ***H04L 41/0869*** (2013.01); ***H04L 41/08*** (2013.01); ***H04L 41/12*** (2013.01); ***H04L 49/70*** (2013.01); *G06F 9/4416* (2013.01); *H04L 45/02* (2013.01)

(58) **Field of Classification Search**
CPC H04L 41/0869; H04L 41/08; H04L 41/12; H04L 49/70; H04L 45/02; G06F 9/4416
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

9,384,061	B1	7/2016	Deivanayagam et al.	
10,348,574	B2	7/2019	Kulkarni et al.	
10,860,362	B2 *	12/2020	Lal	G06F 9/45541
10,972,449	B1 *	4/2021	Levin	H04L 63/10
11,153,168	B1 *	10/2021	Dhamal Gopalarathnam	H04L 41/0869
2016/0014073	A1 *	1/2016	Reddy	H04L 41/5096 713/2
2016/0156522	A1 *	6/2016	Jubran	H04L 41/12 709/224
2017/0026235	A1 *	1/2017	Famaey	H04L 47/827
2017/0054603	A1	2/2017	Kulkarni et al.	
2019/0327144	A1 *	10/2019	Tembey	H04L 41/0869

OTHER PUBLICATIONS

Amazon Web Services, "Amazon Virtual Private Cloud Connectivity Options: AWS Whitepaper", Jun. 6, 2020, 38 pages.

(Continued)

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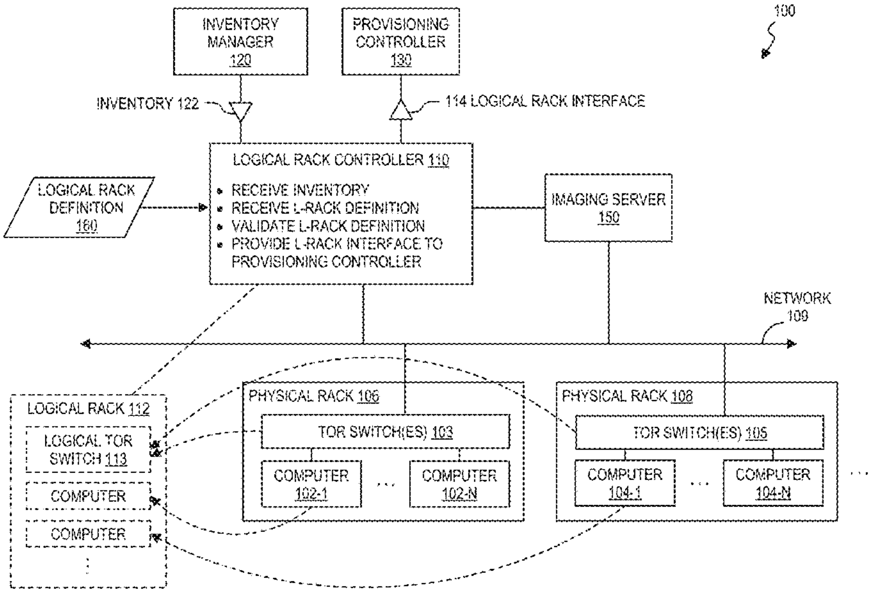
(57) **ABSTRACT**

Example implementations relate to a logical rack controller. In an example, a logical rack controller receives an inventory of a plurality of physical computing racks. The logical rack controller receives a logical rack definition that indicates selected physical infrastructure from among the inventory to form a logical rack. The logical rack controller validates the logical rack definition by verifying network connectivity of the selected physical infrastructure. After validation of the logical rack definition, the logical rack controller provides, to a provisioning controller, an interface to the logical rack. The provisioning controller can utilize the interface to access the logical rack.

17 Claims, 6 Drawing Sheets



(56) **References Cited**

OTHER PUBLICATIONS

Amazon Web Services, "Introducing Five New Amazon EC2 Bare Metal Instances", 4 pages, Feb. 13, 2019, retrieved from internet <https://aws.amazon.com/about-aws/whats-new/2019/02/introducing-five-new-amazon-ec2-bare-metal-instances/>.
DMTF, "Redfish White Paper", Sep. 4, 2018, 16 pages.
Marcon, D. et al.; "PredCloud: Providing predictable network performance in large-scale OpenFlow-enabled cloud platforms through trust-based allacation of resources"; Jul. 21, 2016; 18 pages.
Openstack Foundation, "Understanding Bare Metal service", retrieved on Jun. 9, 2021, 6 pages, retrieved from internet <https://docs.openstack.org/ironic/latest/user/architecture.html>.
Ovhcloud, "vRack", Web page: <https://www.ovh.com/world/solutions/vrack/network-technology.xml>, retrieved on Jan. 14, 2021, 3 pages.
Peng, L. et al.; "A Novel Framework of Distributed Datacenter Networks to Support Intelligent Services: Architecture, Operation, and Solutions"; Dec. 4, 2018; 9 pages.
Wang, R et al.; "Using Empirical Estimates of Effective Bandwidth in Network-Aware Placement of Virtual Machines in Datacenters"; Jun. 2016; 14 pages.
Unified Extensible Firmware Interface (UEFI) Forum, Inc., "Unified Extensible Firmware Interface (UEFI) Specification", Mar. 2021, 2540 pages.

* cited by examiner

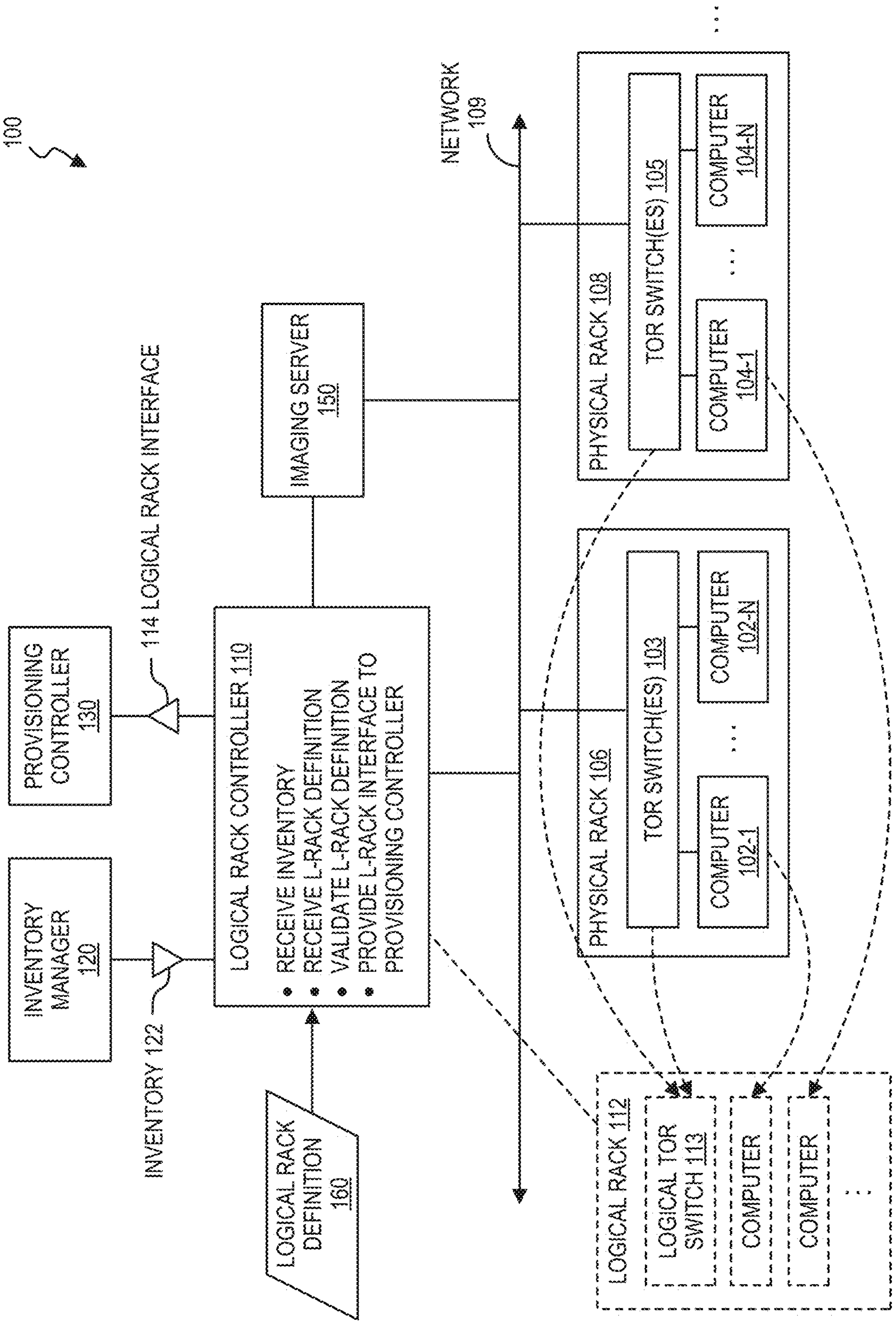

100
INVENTORY MANAGER 120
PROVISIONING CONTROLLER 130
114 LOGICAL RACK INTERFACE
INVENTORY 122
LOGICAL RACK CONTROLLER 110
• RECEIVE INVENTORY
• RECEIVE L-RACK DEFINITION
• VALIDATE L-RACK DEFINITION
• PROVIDE L-RACK INTERFACE TO PROVISIONING CONTROLLER
LOGICAL RACK DEFINITION 160
IMAGING SERVER 150
NETWORK 109
PHYSICAL RACK 106
TOR SWITCH(ES) 103
COMPUTER 102-1
...
COMPUTER 102-N
PHYSICAL RACK 108
TOR SWITCH(ES) 105
COMPUTER 104-1
...
COMPUTER 104-N
...
LOGICAL RACK 112
LOGICAL TOR SWITCH 113
COMPUTER
COMPUTER
...

FIG. 1

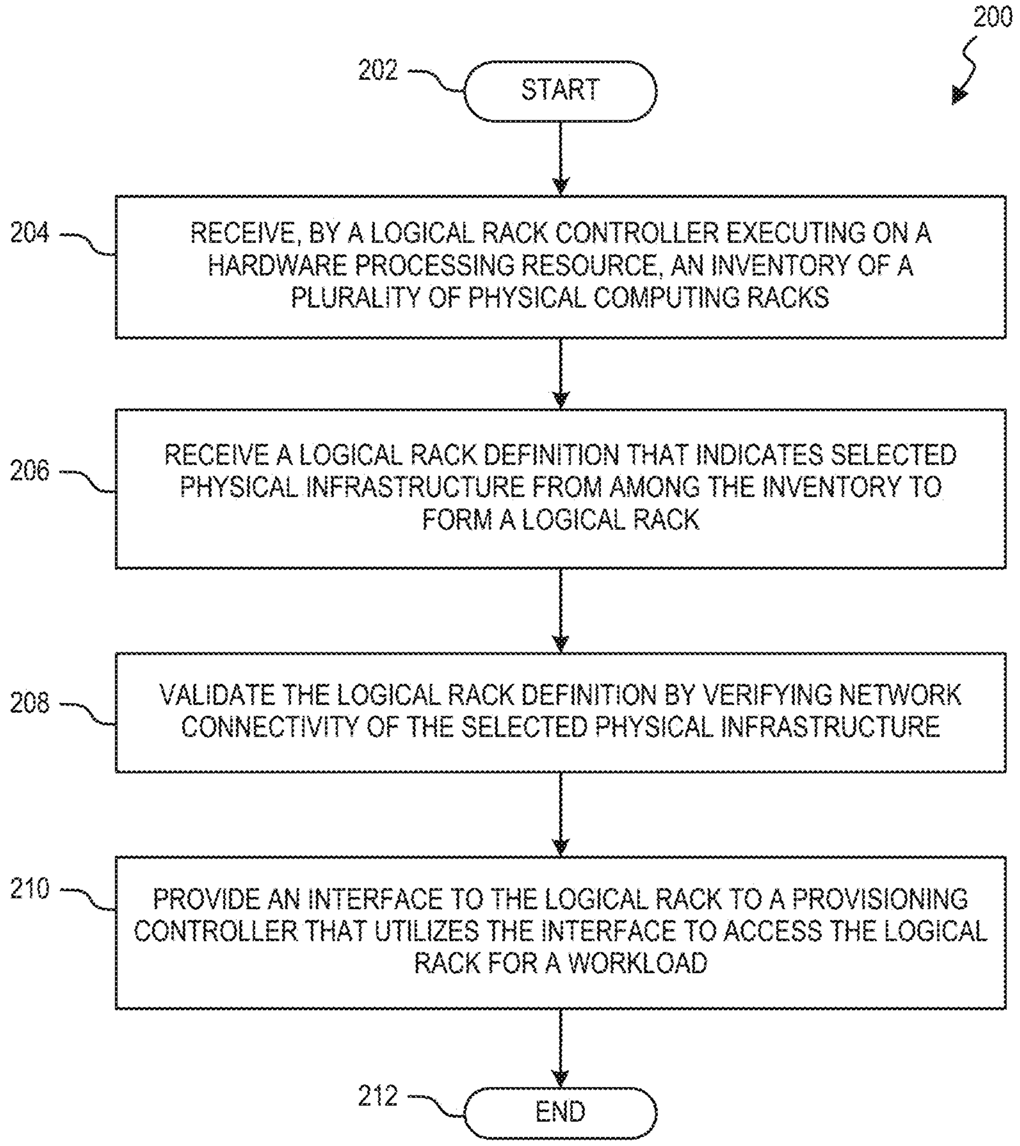

200
202
START
204
RECEIVE, BY A LOGICAL RACK CONTROLLER EXECUTING ON A HARDWARE PROCESSING RESOURCE, AN INVENTORY OF A PLURALITY OF PHYSICAL COMPUTING RACKS
206
RECEIVE A LOGICAL RACK DEFINITION THAT INDICATES SELECTED PHYSICAL INFRASTRUCTURE FROM AMONG THE INVENTORY TO FORM A LOGICAL RACK
208
VALIDATE THE LOGICAL RACK DEFINITION BY VERIFYING NETWORK CONNECTIVITY OF THE SELECTED PHYSICAL INFRASTRUCTURE
210
PROVIDE AN INTERFACE TO THE LOGICAL RACK TO A PROVISIONING CONTROLLER THAT UTILIZES THE INTERFACE TO ACCESS THE LOGICAL RACK FOR A WORKLOAD
212
END

FIG. 2

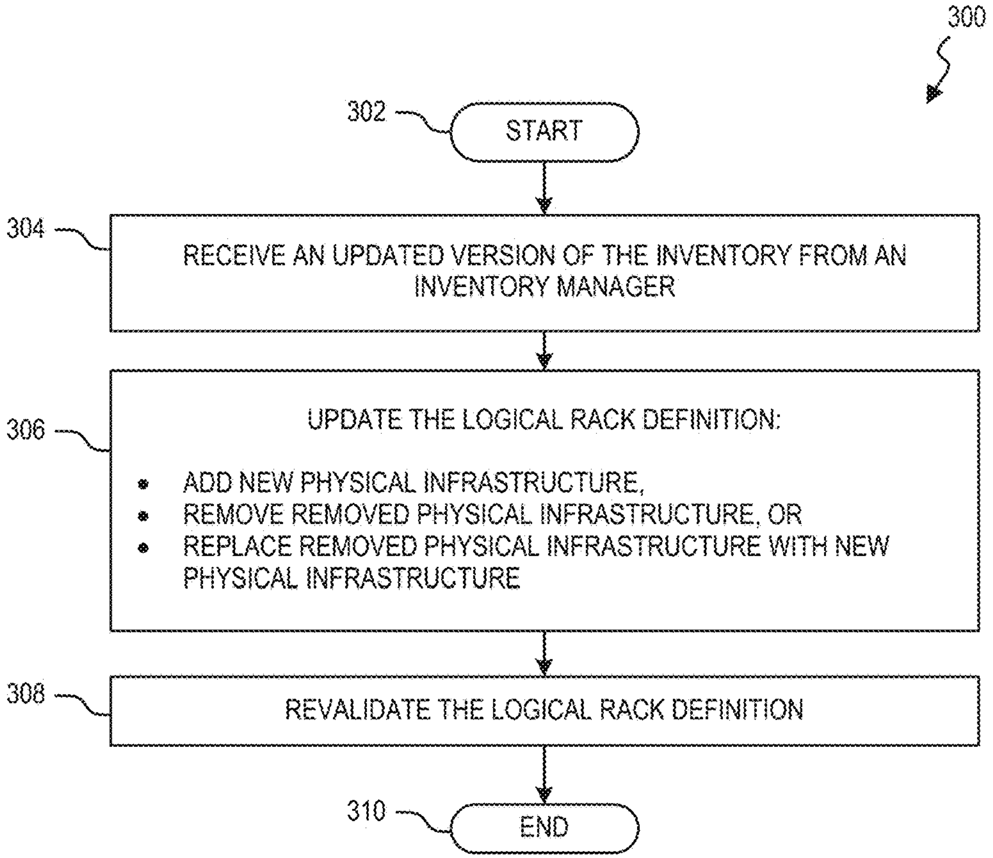

300
302
START
304
RECEIVE AN UPDATED VERSION OF THE INVENTORY FROM AN INVENTORY MANAGER
306
UPDATE THE LOGICAL RACK DEFINITION:
• ADD NEW PHYSICAL INFRASTRUCTURE,
• REMOVE REMOVED PHYSICAL INFRASTRUCTURE, OR
• REPLACE REMOVED PHYSICAL INFRASTRUCTURE WITH NEW PHYSICAL INFRASTRUCTURE
308
REVALIDATE THE LOGICAL RACK DEFINITION
310
END

FIG. 3

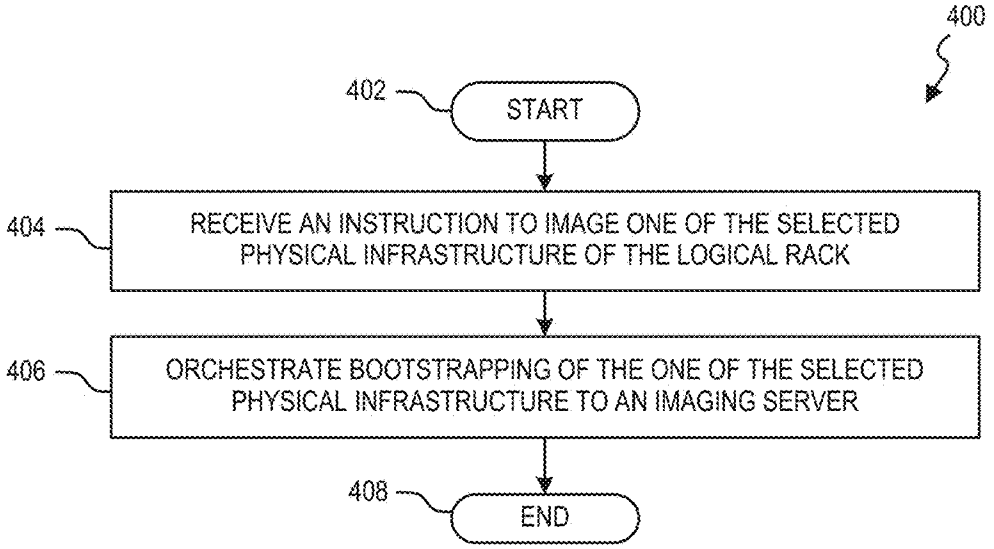

400
402
START
404
RECEIVE AN INSTRUCTION TO IMAGE ONE OF THE SELECTED PHYSICAL INFRASTRUCTURE OF THE LOGICAL RACK
406
ORCHESTRATE BOOTSTRAPPING OF THE ONE OF THE SELECTED PHYSICAL INFRASTRUCTURE TO AN IMAGING SERVER
408
END

FIG. 4

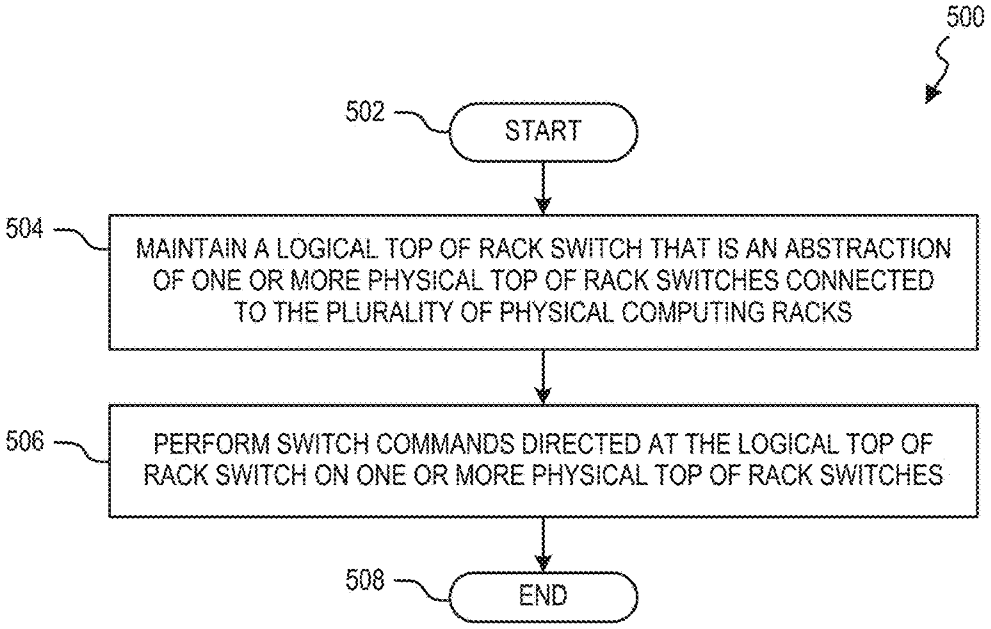

500
502
START
504
MAINTAIN A LOGICAL TOP OF RACK SWITCH THAT IS AN ABSTRACTION OF ONE OR MORE PHYSICAL TOP OF RACK SWITCHES CONNECTED TO THE PLURALITY OF PHYSICAL COMPUTING RACKS
506
PERFORM SWITCH COMMANDS DIRECTED AT THE LOGICAL TOP OF RACK SWITCH ON ONE OR MORE PHYSICAL TOP OF RACK SWITCHES
508
END

FIG. 5

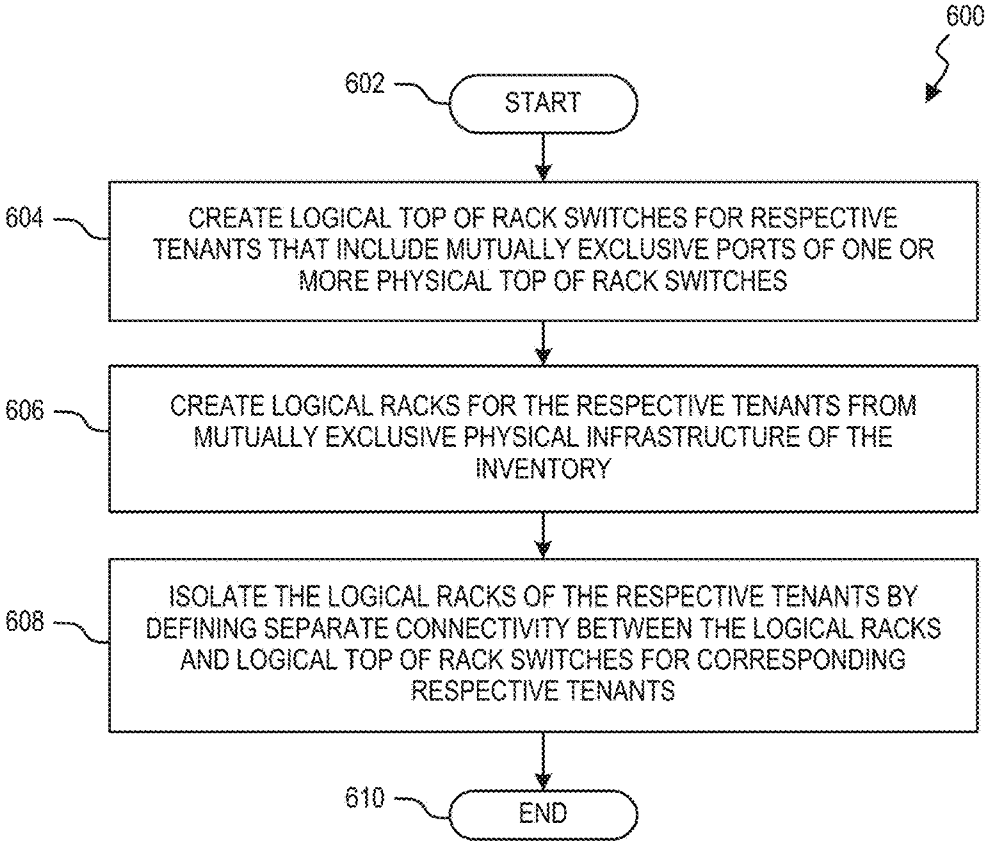

600
602
START
604
CREATE LOGICAL TOP OF RACK SWITCHES FOR RESPECTIVE TENANTS THAT INCLUDE MUTUALLY EXCLUSIVE PORTS OF ONE OR MORE PHYSICAL TOP OF RACK SWITCHES
606
CREATE LOGICAL RACKS FOR THE RESPECTIVE TENANTS FROM MUTUALLY EXCLUSIVE PHYSICAL INFRASTRUCTURE OF THE INVENTORY
608
ISOLATE THE LOGICAL RACKS OF THE RESPECTIVE TENANTS BY DEFINING SEPARATE CONNECTIVITY BETWEEN THE LOGICAL RACKS AND LOGICAL TOP OF RACK SWITCHES FOR CORRESPONDING RESPECTIVE TENANTS
610
END

FIG. 6

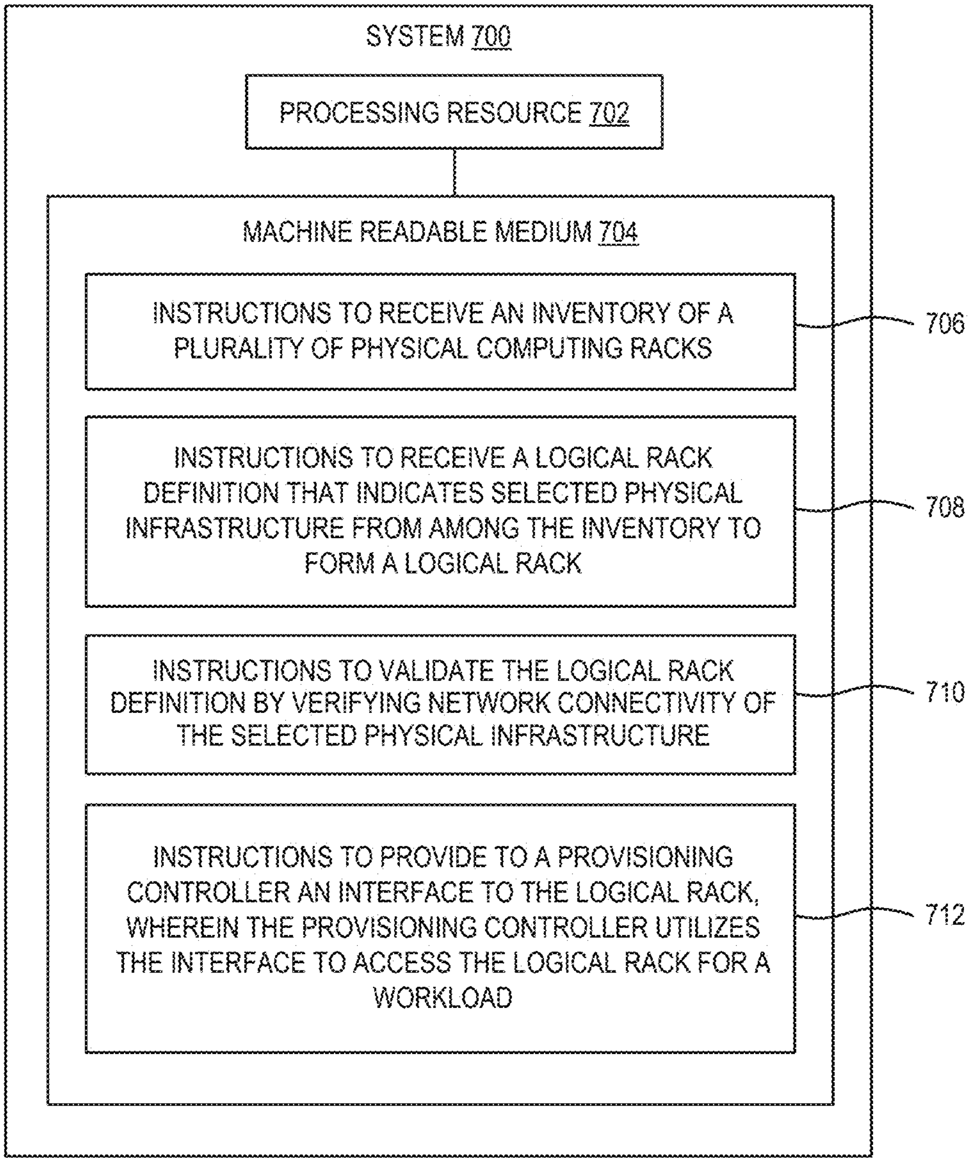

SYSTEM 700
PROCESSING RESOURCE 702
MACHINE READABLE MEDIUM 704
INSTRUCTIONS TO RECEIVE AN INVENTORY OF A PLURALITY OF PHYSICAL COMPUTING RACKS
706
INSTRUCTIONS TO RECEIVE A LOGICAL RACK DEFINITION THAT INDICATES SELECTED PHYSICAL INFRASTRUCTURE FROM AMONG THE INVENTORY TO FORM A LOGICAL RACK
708
INSTRUCTIONS TO VALIDATE THE LOGICAL RACK DEFINITION BY VERIFYING NETWORK CONNECTIVITY OF THE SELECTED PHYSICAL INFRASTRUCTURE
710
INSTRUCTIONS TO PROVIDE TO A PROVISIONING CONTROLLER AN INTERFACE TO THE LOGICAL RACK, WHEREIN THE PROVISIONING CONTROLLER UTILIZES THE INTERFACE TO ACCESS THE LOGICAL RACK FOR A WORKLOAD
712

FIG. 7

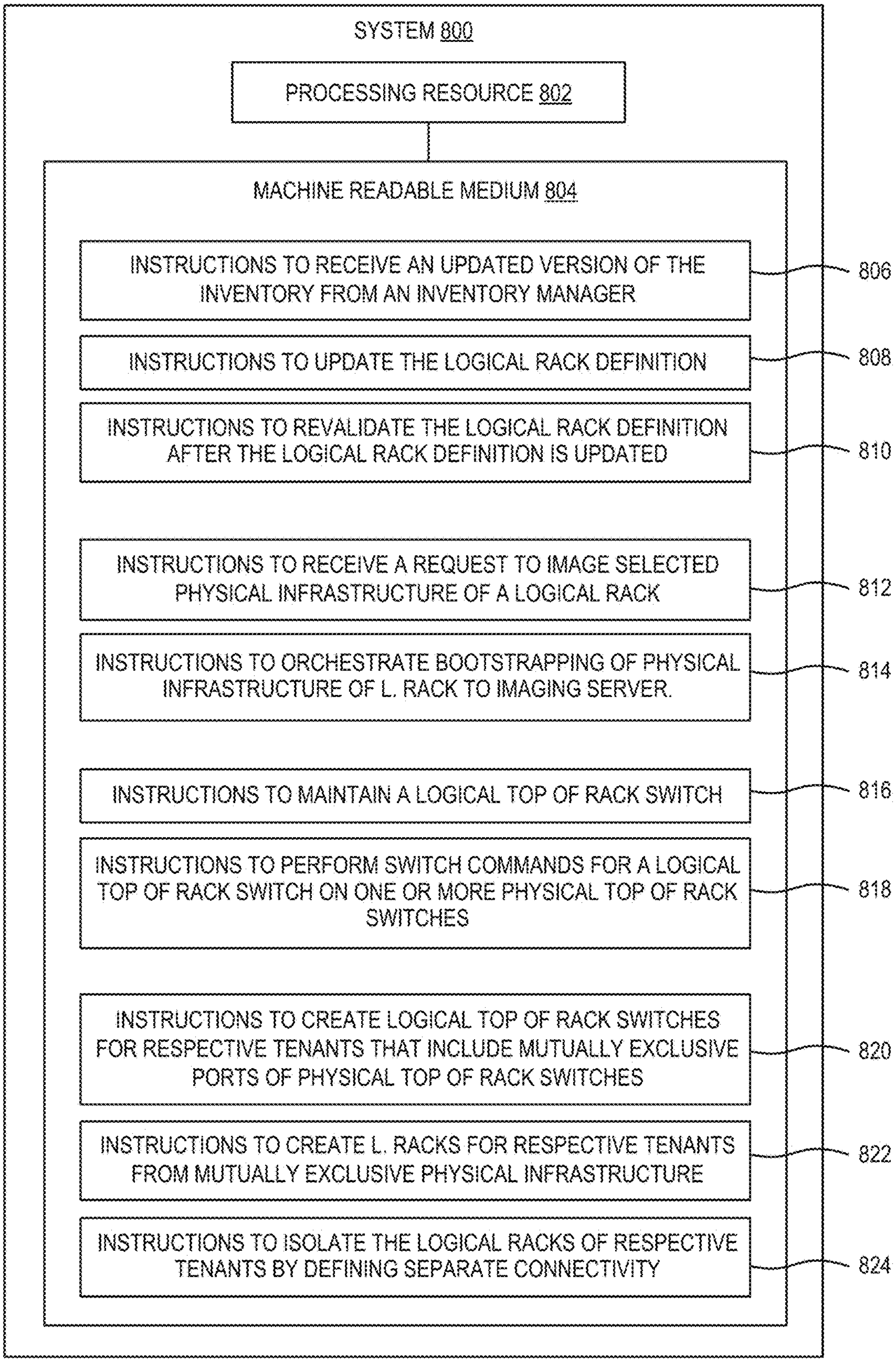

SYSTEM 800
PROCESSING RESOURCE 802
MACHINE READABLE MEDIUM 804
INSTRUCTIONS TO RECEIVE AN UPDATED VERSION OF THE INVENTORY FROM AN INVENTORY MANAGER
806
INSTRUCTIONS TO UPDATE THE LOGICAL RACK DEFINITION
808
INSTRUCTIONS TO REVALIDATE THE LOGICAL RACK DEFINITION AFTER THE LOGICAL RACK DEFINITION IS UPDATED
810
INSTRUCTIONS TO RECEIVE A REQUEST TO IMAGE SELECTED PHYSICAL INFRASTRUCTURE OF A LOGICAL RACK
812
INSTRUCTIONS TO ORCHESTRATE BOOTSTRAPPING OF PHYSICAL INFRASTRUCTURE OF L. RACK TO IMAGING SERVER.
814
INSTRUCTIONS TO MAINTAIN A LOGICAL TOP OF RACK SWITCH
816
INSTRUCTIONS TO PERFORM SWITCH COMMANDS FOR A LOGICAL TOP OF RACK SWITCH ON ONE OR MORE PHYSICAL TOP OF RACK SWITCHES
818
INSTRUCTIONS TO CREATE LOGICAL TOP OF RACK SWITCHES FOR RESPECTIVE TENANTS THAT INCLUDE MUTUALLY EXCLUSIVE PORTS OF PHYSICAL TOP OF RACK SWITCHES
820
INSTRUCTIONS TO CREATE L. RACKS FOR RESPECTIVE TENANTS FROM MUTUALLY EXCLUSIVE PHYSICAL INFRASTRUCTURE
822
INSTRUCTIONS TO ISOLATE THE LOGICAL RACKS OF RESPECTIVE TENANTS BY DEFINING SEPARATE CONNECTIVITY
824

FIG. 8

LOGICAL RACK CONTROLLER

BACKGROUND

Computing infrastructure may include compute, storage, and networking devices organized into racks. Servers within a rack may communicate with each other via a top-of-rack switch.

BRIEF DESCRIPTION OF THE DRAWINGS

Various examples will be described below with reference to the following figures.

FIG. **1** is a block diagram of an example system that includes a logical rack controller.

FIG. **2** is a flow chart of an example method that provides an interface to a logical rack.

FIG. **3** is a flow chart of an example method that updates a logical rack definition.

FIG. **4** is a flow chart of an example method that orchestrates bootstrapping of infrastructure to an imaging server.

FIG. **5** is a flow chart of an example method that performs switch commands directed at a logical top of rack switch.

FIG. **6** is a flow chart of an example method that creates logical racks for respective tenants.

FIG. **7** is a block diagram of an example system with a machine readable medium that includes instructions to provide an interface to a logical rack.

FIG. **8** is a block diagram of an example system with a machine readable medium that includes instructions related to logical racks and logical top of rack switches.

DETAILED DESCRIPTION

Computing infrastructure may include compute devices such as servers, storage devices such as storage arrays, and networking devices such as switches. Various combinations of such infrastructure may be organized into a physical rack, One or more physical racks may form at least part of a private cloud that resides in an operator's data center or at a colocation facility or may form at least part of a public cloud provided by a public cloud vendor for consumption by an operator. An operator may be understood to be an individual, an organization, a company, an institution, or the Ike, and may be an end user of the infrastructure. Infrastructure may be provided to an operator by a vendor and purchased, leased, rented, or paid for on a consumption-basis by the operator. In some cases, the operator may be a customer of the vendor.

Bare metal infrastructure describes physical computing infrastructure, including bare metal servers for example. Virtualization technology such as hypervisors or virtual machines may be run on the bare metal infrastructure. Bare metal infrastructure may be assembled into bare metal racks. Running applications and workloads directly on bare metal infrastructure may provide benefits such as performance, security, and availability (such benefits may be by comparison to virtual infrastructure, for example). Bare metal infrastructure may be useful in certain use cases, such as machine learning operations workloads, high performance computing workloads, computing tasks that involve direct hardware access, and workloads requiring performance, security, and/or availability.

Generally, management of bare metal infrastructure involves intimate familiarity with the details of the physical configuration of the infrastructure. As such, bare metal infrastructure may carry disadvantages that reduce its flexibility. For example, an operator or user of the bare metal infrastructure may be constrained to use what exists within a given physical rack. An operator may be expected to understand how physical racks are physically connected to the physical and logical (e.g., underlay and overlay) networks, how the networks interconnect infrastructure inside a rack and across racks, how power is supplied to the infrastructure, and more, Since an operator needs to be aware of the details of each physical rack, scaling up capabilities to multiple physical racks becomes an expensive and time-intensive operation. Thus, it would be useful to provide complex racks of bare metal infrastructure in a flexible manner that is highly scalable and repeatable across numerous (e.g., hundreds or thousands) of deployments at the lowest cost possible.

To address the foregoing technical challenges, examples described herein relate to a logical rack controller that abstracts management of large collections of infrastructure, such as racks of infrastructure. The logical rack controller can create and maintain a logical rack according to a logical rack definition and using physical infrastructure (e.g., bare metal servers) from different physical racks as the inventory for that logical rack. In some implementations, the different physical racks may be geographically separated. A logical rack may be understood to represent an abstraction of physical infrastructure, or in other words, a logical rack may be a collection of physical infrastructure organized in a different manner than in physical reality, as will be described further below.

The logical rack controller can also maintain a notion of one or more logical top of rack switches that abstract physical top of rack switches that connect the physical infrastructure. The logical rack controller may handle management of the network topology of physical infrastructure within the logical rack, including validation of network connectivity within the logical rack. The logical rack controller can make the logical rack available to a provisioning controller, and the provisioning controller may perform lifecycle management of the logical rack for use by an application workload.

Thus, by virtue of the foregoing, a logical rack may be created from bare metal servers and provided as infrastructure for use by workloads with reduced or minimal intervention by and knowledge of an operator. Accordingly, physical infrastructure may be flexibly configured, deployed, and/or utilized at scale and in a cost-efficient manner. Moreover; the logical rack controller may create a logical rack from infrastructure spanning multiple physical racks with different top of rack switches, without relying on a controller in or for each of the physical racks, thus reducing complexity and cost.

Referring now to the figures. FIG. **1** depicts physical infrastructure, including computers **102-1** through **102**-N (collectively computers **102**) and computers **104-1** through **104**-N (collectively computers **104**). The computers **102**, **104** may be general purpose servers, high performance computing systems, hyperconverged infrastructure, inferencing or training systems, or other computing devices. The computers **102**, **104** may be bare metal infrastructure. Computers may be arranged into an enclosure known as a physical computing rack. For example, computers **102** may be included in a first physical rack **106**, and computers **104** may be included in a second physical rack **108**. The physical racks **106**, **108** may be located in a same data center or in geographically separated data centers. The data centers may be owned by or leased by an operator, and as such, the physical racks **106**, **108** form at least part of an on-premise private cloud of the operator.

A physical rack may include other infrastructure, such as storage appliances (e.g., a storage array) and networking infrastructure (e.g., switches), and although the present description relates to assembling computers into a logical rack, the techniques described herein may be used for other infrastructure also. A physical rack may also include one or more top of rack switches (also referred to as TOR switches), which are connected to each of the computers in that physical rack via down links. Multiple TOR switches may be provided in a physical rack for high availability. TOR switches may enable computers to communicate with each other within a rack and to communicate with an intranet (e.g., within the data center) and/or the Internet through uplinks to aggregation switches. In FIG. **1**, physical TOR switch(es) **103** are provided in physical rack **106** and physical TOR switch(es) **105** are provided in physical rack **108**. Accordingly, the physical racks **106**, **108** may communicate across a network **109**.

A logical rack controller **110** is provided, which communicates with the infrastructure in the physical racks **106**, **108**, In some examples, the logical rack controller **110** may be implemented as software instructions encoded on a non-transitory machine readable medium and executed on a hardware processing resource. For example, a processing resource may include a microcontroller, a microprocessor, a central processing unit (CPU), a graphics processing unit (GPU), a data processing unit (DPU), an application-specific integrated circuit (ASIC), a field programmable gate array (FPGA), a system-on-a-chip (SOC), etc., and a machine readable medium may include random access memory (RAM), read-only memory (ROM), electrically erasable programmable read-only memory (EEPROM), flash memory, a hard disk drive, etc. In some examples, the logical rack controller **110** may include electronic circuitry. In some examples, the logical rack controller **110** may be implemented on a smart network interface card (SmartNIC). In some examples, the logical rack controller **110** may be a containerized application (e.g., a container pod) or a virtual machine executing on a hardware processing resource of a computer that is involved in management of the infrastructure in system **100** by communication over the network **109**.

The logical rack controller **110** may be in communication with an inventory manager **120** and a provisioning controller **130**. In some implementations, the inventory manager **120** may be software executing on a hardware processing resource of a computer. The inventory manager **120** maintains an inventory of the physical infrastructure, such as the computers **102**, **104**, that is present in the system **100**. The inventory may be a data structure. The inventory manager **120** may also add or remove infrastructure from the inventory as infrastructure is added (e.g., by connection to the network **109**, etc.) or removed (e.g., by failure, by disconnection to network **109**, etc.).

The provisioning controller **130** may be software executing on a hardware processing resource of a computer, and in some cases, may be executing in a cloud and included at or accessible via a cloud-based portal. The provisioning controller **130** may be a Software-as-a-Service (SaaS) portal and may have the functionality described below. The provisioning controller **130** may be a bare metal controller or a bare metal as-a-service controller. The logical rack controller **110**, as well as the inventory manager **120** in some instances, may communicate with the provisioning controller **130** via the Internet.

In some implementations, physical racks **106**, **108** may be owned by or in possession of an operator and managed by a vendor. In some implementations, physical racks **106**, **108** may be delivered to the operator by a vendor for consumption as-a-service by the operator in a pay-per-use financial model. In these implementations, the logical rack controller **110**, as well as the inventory manager **120** in some instances, may be implemented as software (e.g., containerized applications or virtual machines) executing on a processing resource of one or more on-premise gateway computers that are at a same data center as one or more of the physical racks **106**, **108**, and are accessed and utilized by the vendor to manage aspects of the infrastructure. In some implementations, the logical rack controller **110**, as well as the inventory manager **120** in some instances, may be executing in a cloud or cloud-based SaaS service. In some implementations, the inventory manager **120** and the logical rack controller **110** are integrated together into a policy controller.

The logical rack controller **110** may consume an infrastructure inventory of the plurality of physical computing racks **106**, **108**. The inventory may include at least an indication of server infrastructure, such as the computers **102**, **104**. In some implementations, as part of building the infrastructure by the vendor prior to delivery to the operator (also referred to as Day 0 operations, e.g., at a factory), the gateway computer on which the inventory manager **120** or the logical rack controller **110** is to be executed may be factory preloaded (e.g., with a configuration script) or otherwise provided with a predefined inventory that is a list of the to-be-delivered physical infrastructure. A predefined inventory may also define that a particular physical TOR switch is connected with all computers of a particular rack. The logical rack controller **110** may receive inventory **122** from the inventory manager **120** or may be itself initially preloaded with the inventory. In some implementations, the aforementioned preloaded inventory may be a seed or starting point, and additional inventory details may be determined by an automated discovery process described below.

As mentioned above, an established inventory manager **120** (e.g., as part of Day 1+ operations after delivery of infrastructure to the operator) may also maintain an updated inventory by either receiving manually provided updates (e.g., an updated configuration script similar to a factory preloaded inventory described above) or auto-detecting the addition of infrastructure or removal of infrastructure from the system **100** by, for example, detecting changes in network connections advertised by infrastructure on the network **109**.

In some implementations, information about the capabilities of the computers in the inventory may be discovered via baseboard management controllers of the computers, infrastructure management protocol communications, network discovery information (e.g., via Link Layer Discovery Protocol), and other discovery techniques. The inventory manager **120** and/or the logical rack controller **110** may perform the discovery. In some implementations, the logical rack controller **110** may perform the discovery and inform the provisioning contra ler **130** about the discovered infrastructure, while the inventory manager **120** listens to the provisioning controller **130** for infrastructure information. Capabilities may include processor, memory, storage, graphics processing unit (CPU), and other hardware, firmware, and software characteristics of the computers, and the capabilities may be stored in the inventory or in a separate data structure.

The logical rack controller **110** may receive a logical rack definition **160** that indicates selected physical infrastructure from among the inventory to form a logical rack **112**. (Logical rack may be abbreviated "L-rack" in the Figures for conciseness). In some implementations, Day 0 operations at the vendor factory may involve defining in a logical rack definition **160** which infrastructure from the predefined inventory is to form a logical rack **112**, and the gateway computer on which the logical rack controller **110** is executed may be factory preloaded or otherwise provided with that predefined logical rack definition **160**. In other examples, during Day 1+ operations for example, a logical rack definition **160** may be provided by the operator or by the vendor (e.g., via the on-premise gateway).

The logical rack definition **160** may be a JSON (JavaScript Object Notation)-based model (i.e., a software construct) that maps physical infrastructure to a logical rack. In some implementations, the selected physical infrastructure indicated in the logical rack definition **160** may include computers, such as one or more of the computers **102**, **104**. Thus, a logical rack **112** may be (but is not necessarily) composed of computers (e.g., **102-1**, **104-1**) from different physical racks (e.g., **106**, **108** respectively). The logical rack definition **160** may be designed for a particular workload. For example, a machine learning operations workload may select physical computer infrastructure from the inventory with CPUs.

In some implementations, the logical rack controller **110** may maintain the notion of a logical TOR switch **113** that is an abstraction of some or all of one or more physical TOR switches (e.g., **103** or **105**) connected to the infrastructure of physical computing racks (**106**, **108**). A logical TOR switch **113** may be a software model or construct, for example. The logical TOR switch **113** may be part of the logical rack definition **160** or may be a separate model associated with the logical rack definition **160**.

From the perspective of a control plane in the system **100**, a logical TOR switch **113** operates in a similar manner to a physical switch and supports similar management capabilities. For example, the logical TOR switch model may map some or all of the ports of one or more physical TOR switches **103**, **105** to the ports of the logical TOR switch **113**. Commands directed to logical TOR switch ports, such as VLAN (virtual local area network) or VXLAN (virtual extensible local area network) commands, link operations, telemetry commands, and the like will be directed via the logical rack controller **110** to the mapped ports of the physical TOR switch **103**, **105**.

To illustrate, FIG. **1** depicts in dashed lines a logical rack **112** that includes a logical TOR switch **113** modeled as a combination of ports of physical TOR switches **103**, **105**. By mapping ports of physical TOR switches **103**, **105** in different physical racks **106**, **108** to ports of a logical TOR switch **113**, computers **102-1**, **104-1** connected to the different physical TOR switches **103**, **105** in separate physical racks **106**, **108** can be combined into a single logical rack **112**. Moreover, such a logical rack **112** may comprise bare metal computers **102**, **104**.

The logical rack definition **160** may specify which port(s) of a physical TOR switch a computer in the definition **160** is connected to. In some implementations, the logical rack definition **160** is factory predefined with this information, which may match the factory cabling of the physical rack. In some implementations, free and unused ports on physical TOR switches may be connected to a discovery network, installations of physical infrastructure (e.g., computers) may be connected to the free ports, and a service monitoring traffic on the discovery network (e.g., traffic such as DHCP

requests) can initiate discovery of which newly installed computer is connected to which previously free port.

In addition to or as an alternative to Day 0 predefinition as a means to generate a logical rack definition **160**, other techniques of creating or modifying a logical rack definition **160** may be utilized. In an example, the logical rack definition **160** may be manually defined, by the vendor or operator, at any point in time (e.g., Day 1+). Another example technique may be based on network visibility of physical infrastructure, where a logical rack definition **160** may be automatically generated from or modified to include any physical infrastructure that is newly detected and visible on the network **109**, such as by a discovery method described above.

A policy driven logical rack membership may be another example technique. The logical rack controller **110** may be provided with a specification of desired characteristics for a logical rack. The characteristics may indicate, for example, "general compute workload", "machine learning operations workload", "CPU intensive", "memory intensive", "storage intensive", "GPU intensive", or the like. The logical rack controller **110** may have a policy or policies (i.e., rules or logic) to automatically create a logical rack definition **160** from inventory that aligns with the specified desired characteristics. For example, a policy may indicate that if "machine learning operations workload" is a desired characteristic, then computers with GPUs should be added to the logical rack. A policy may also indicate that computers without GPUs should be utilized for "general compute" logical racks, for example.

Having received a logical rack definition **160**, the logical rack controller **110** reads and validates the logical rack definition **160** by verifying network connectivity of the selected physical infrastructure identified in the logical rack definition **160**. Validation may include one or more of verifying that all physical infrastructure (e.g., computers **102**, **104**) in the logical rack definition **160** exist, verifying that any TOR switches (e.g., **103**, **105**) associated with the logical rack definition **160** exist, and verifying the existence of TOR switch-to-computer connections.

For example, the logical rack controller **110** may utilize information from the TOR switches **103**, **105** through the Link Layer Discovery Protocol (LLDP) to perform the validation. Also, the logical rack controller **110** may utilize LLDP information to verify the existence of high availability links between each computer and more than one TOR switch. Accordingly, the logical rack controller **110** can use the LLDP information to verify that the logical rack model (e.g., connectivity between computers and a logical TOR switch **113** made up of physical TOR switches **103**, **105**) matches the physical reality. Other discovery protocols may be used in other implementations.

In some implementations, if the logical rack definition **160** fails validation (e.g., a piece of physical infrastructure does not exist or is not connected to the physical TOR switches as expected), an error condition may be reported, to the Saab portal or to the vendor for example. In some implementations, the logical rack controller **110** may attempt to automatically correct the validation errors by removing the non-validated physical infrastructure from the logical rack definition **160**. In some implementations, the logical rack controller **110** may attempt to correct the validation errors by auto-detecting the correct network connections between physical TOR switches and the physical infrastructure and updating the logical rack definition **160** accordingly.

After the logical rack definition **160** has been validated (or corrected), the logical rack controller **110** persists the logical rack definition **160** by providing a logical rack interface **114** (which may be a set of interfaces) to the provisioning controller **130**, In some implementations, the logical rack interface **114** may be defined based on the requirements or design of the provisioning controller **130** in order for the provisioning controller **130** to carry out a variety of tasks. For example, the interface **114** may provide a means (e.g., commands) for the provisioning controller **130** to prepare the logical rack **112** for an operation or application workload of the operator. More particularly, the provisioning controller **130** may use the interface **114** to communicate a request to the logical rack controller **110** to image or reimage one or more of the physical infrastructure (e.g., computer **102**, **104**) of the logical rack **112**. To provision the operating system, the logical rack controller **110** may orchestrate bootstrapping of that physical infrastructure to an imaging server **150**. For example, in an implementation, the logical rack controller **110** may use an infrastructure management protocol, such as the DMTF (Distributed Management Task Force) Redfish® standard, to reboot a computer **102** or **104** to a state that will communicate with an imaging server **150** (e.g., HTTPS boot to the imaging server), from which the computer **102** or **104** will install an operating system (OS) image.

In some implementations, the logical rack interface **114** may provide an interface by which the provisioning controller **130** may perform switch commands (e.g., commands related to configuration, performance, fault management, etc. of a switch) against the logical TOR switch **113** and/or physical TOR switches **103**, **105**. If commands are targeted at specific ports of a logical TOR switch **113**, the logical rack controller **110** may map the commands to corresponding ports of a physical TOR switch **103**, **105** according to the logical TOR switch model.

In some implementations, the logical rack interface **114** may provide an interface by which the provisioning controller **130** may manage one or more power distribution units (PDUs) of a physical rack **106**, **108** that are associated with the logical rack **112**. For example, certain PDUs may provide software control of the power state for a rack or for individual units of infrastructure within a rack. Thus, in response to a command over interface **114** to turn power on or off to a logical rack **112**, the logical rack controller **110** may command the PDUs of the physical racks **106** or **108** housing the computers of the logical rack **112** to turn power on or off to those specific computers.

In some implementations, the logical rack controller **110** may abstract aspects of the computers of a logical rack **112**, such as interfaces and connectivity (e.g., out-of-band communications, management network interfaces, serial ports, parallel ports, universal serial bus ports, etc.), and allow for control of those aspects by the provisioning controller **130** through the logical rack interface **114**.

In some implementations, the logical rack controller **110** may also provide the provisioning controller **160** with information about the capabilities of the constituent computers of the logical rack **112**, as discovered in the manner discussed above. By virtue of the capabilities information, the provisioning controller **130** may intelligently optimize the logical rack **112** for the operator's workload.

As discussed above, the inventory manager **120** may update the inventory as physical infrastructure available in system **100** changes. For example, new infrastructure may be added to the system **100** for various reasons such as an operator's increased capacity demands. Infrastructure may be removed from the system **100** for various reasons such as failure, decreased capacity demands, or reallocation to a different system. Infrastructure may be replaced (i.e., a combination of removing and adding) for various reasons such as replacement of failed infrastructure. The logical rack controller **110** may watch for changes at the inventory manager **120** or the inventory manager **120** may inform the logical rack controller **110** of changes. The logical rack controller **110** may receive an updated inventory **122** from the inventory manager **120**.

In response to the changes in the updated inventory **122**, the logical rack controller **110** may update the logical rack definition **150** by adding new physical infrastructure, removing the removed physical infrastructure, or replacing removed physical infrastructure with new physical infrastructure, in the previously validated logical rack definition **160**. For example, the logical rack controller **110** may utilize policy driven logical rack membership as described above to add new infrastructure based on matching characteristics of an existing logical rack definition **160**. Alternatively, newly added infrastructure may be claimed by added by default, for example, to a logical rack **112** that is associated with a logical TOR switch **113** that is mapped to physical TOR switch **103**, **105** ports connected to the newly added infrastructure. As another alternative, the logical rack definition **160** may be manually edited. The logical rack controller **110** may revalidate the modified logical rack definition **160** in a similar manner to validation described above.

In some implementations, a logical rack controller **110** may also support multi-tenancy, where multiple logical racks are defined from the same inventory of physical infrastructure and at least some of the logical racks belong to different tenants. Different tenants can represent different operators or the same operator desiring isolation between workloads. To provide isolation between tenants, logical TOR switches are created for respective tenants that include mutually exclusive ports of physical TOR switches placed on isolated VLANs or VXLANs. In other implementations, other network isolation techniques may be utilized, Physical infrastructure connected to those logical TOR switches may be from the same inventory but are mutually exclusive to respective tenants. Thus, logical racks of respective tenants are isolated due to separate connectivity between the logical racks and logical TOR switches for respective tenants.

In some implementations, multiple logical rack controllers **110** or multiple instances of logical rack controller **110** may run concurrently in the system **100**. For example, one logical rack controller or instance thereof may be deployed for each individual logical rack. For example, where a logical rack controller is run as a container pod, additional logical rack controller instances may be deployed as replicas by a container orchestrator. Separate logical racks created from the same inventory of physical infrastructure may be error-checked, using certificates or universally unique identifiers of computers for example, to ensure that any given computer is claimed by only one logical rack and associated logical rack controller.

For the sake of illustration, two racks **106**, **108** and their included infrastructure are depicted, but it should be understood that the techniques described herein may be utilized with a different quantity of racks and different arrangements of infrastructure included therein. Additionally, the logical rack **112** is depicted as being comprised of elements of the racks **106**, **108** (via the dashed arrows), but it should be understood that other logical racks may be created with different arrangements of infrastructure.

FIGS. **2-6** are flow diagrams depicting various example methods. In some implementations, one or more blocks of the methods may be executed substantially concurrently or in a different order than shown. In some implementations, a method may include more or fewer blocks than are shown. In some implementations, one or more of the blocks of a method may, at certain times, be ongoing and/or may repeat. In some implementations, blocks of the methods may be combined.

The methods shown in FIGS. **2-6** may be implemented in the form of executable instructions stored on a machine readable medium and executed by a processing resource and/or in the form of electronic circuitry. For example, aspects of the methods may be described below as being performed by a logical rack controller that is executing on a hardware processing resource (e.g., a CPU, a GPU, a DPU, an ASIC, an FPGA, an SOC, etc.). For example, the hardware processing resource may be part of an on-premise gateway computer installed at an operator's data center or coloration. Additionally, other aspects of the methods described below may be described with reference to other elements shown in FIG. **1** for non-limiting illustration purposes.

FIG. **2** is a flow diagram depicting an example method **200**. Method **200** starts at block **202** and continues to block **204** where a logical rack controller **110** executing on a hardware processing resource receives an inventory **122** about a plurality of physical computing racks **106**, **108** (more or fewer racks are also contemplated). The inventory **122** may be retrieved from or sent by an inventory manager **120**.

At block **206**, the logical rack controller **110** receives a logical rack definition **160** that indicates selected physical infrastructure from among the inventory **122** to form a logical rack **112**. As described above, the logical rack definition **160** may be generated by predefinition, manual definition, based on network visibility, based on policy driven logical rack membership, or other techniques.

At block **208**, the logical rack controller **110** validates the logical rack definition by verifying network connectivity of the selected physical infrastructure. For example, the logical rack controller **110** may utilize LLDP information from a rack switch (e.g., **103**, **105**) associated with the logical rack definition **160** to confirm connectivity between the top of rack switch (e.g., **103**, **105**) and the computers (e.g., **102**, **104**) in the logical rack definition **160**.

In some implementations, if the logical rack definition **160** fails validation, an error condition may be reported to the SaaS portal or otherwise to the vendor. Additionally or alternatively, the logical rack controller **110** may attempt to correct the validation errors in a manner described above.

After the logical rack definition is validated, at block **210**, the logical rack controller **110** provides an interface **114** to the logical rack **112** to a provisioning controller **130**. In some implementations, the provisioning controller **130** may be included in a SaaS portal in the cloud operated by the infrastructure vendor. The interface **114** (which may be a set of interfaces) may be used by the provisioning controller **130** to prepare and use the logical rack **112** for the operator's workload, such as machine learning operators or other workloads. The method **200** ends at block **212**.

FIG. **3** is a flow diagram depicting an example method **300**. Method **300** may be useful in some logical rack lifecycle scenarios such as, for example, when physical infrastructure is added, removed, or replaced in the inventory. Method **300** starts at block **302** and continues to block **304** where the logical rack controller **110** receives an updated version of the inventory **122** from the inventory manager **120**.

At block **306**, the logical rack controller **110** updates the logical rack definition **160** by adding new physical infrastructure indicated in the updated version of the inventory **122** to the logical rack definition **160**, removing removed physical infrastructure as indicated in the updated version of the inventory **122** from the logical rack definition **160**, or by replacing the removed physical infrastructure with the new physical infrastructure in the logical rack definition **160**.

At block **308**, the logical rack controller **110** revalidates the updated logical rack definition **160**. In some implementations, the logical rack controller **110** may provide an updated logical rack interface **114** to the provisioning controller **130**, such that the provisioning controller **130** is notified of changes to the logical rack **112**. The method **300** ends at block **310**.

FIG. **4** is a flow diagram depicting an example method **400**. Method **400** may be useful for imaging a validated logical rack **112**, which may be further useful for preparing the logical rack **112** for lifecycle management operations on the physical infrastructure represented by the logical rack **112**. The method **400** starts at block **402** and continues to block **404** where the logical rack controller **110** receives an instruction from the provisioning controller **130** (e.g., via the logical rack interface **114**) to image one or more of the selected physical infrastructure (e.g., a computer **102**, **104**) of the logical rack **112**.

At block **406** and in response to the instruction, the logical rack controller **110** may orchestrate bootstrapping of the one of the selected physical infrastructure (e.g., computer **102**, **104**) to an imaging server **150**. For example as discussed above, the logical rack controller **110** may use an infrastructure management protocol to boot the computer **102**, **104** to the imaging server **150** from which an OS image is installed on the computer **102**, **104**. The method **400** ends at block **408**.

FIG. **5** is a flow diagram depicting an example method **500**. Method **500** may be useful providing and managing a logical top of rack switch (e.g., **113**), which may be used by the provisioning controller **130** and other parts of the environment such as a data center control plane as if it were a physical TOR switch.

The method **500** starts at block **502** and continues to block **504** where the logical rack controller **110** maintains a logical TOR switch **113** that is an abstraction of at least a portion of one or more physical top of rack switches (e.g., **103**, **105**, etc.). In some implementations, the logical TOR switch **113** is a software model that maps ports of the logical TOR switch **113** to ports of one or more physical TOR switches. In some examples, the logical TOR switch **113** may map to a some (e.g., a subset) or all ports of one or more physical TOR switches. Different physical TOR switches may be connected to separate respective physical computing racks (e.g., **106**, **108**, etc.).

In some implementations, the logical rack controller **110** may provide an interface to the logical TOR rack **113**, which may be accessed by the provisioning controller **130** for example. The provisioning controller **130** or other software or hardware modules may send switch commands to the logical TOR switch **113** via that interface. The switch commands may relate, for example to configuration, performance, fault management, etc., and may target specific ports of the logical TOR switch **113**.

At block **506**, the logical rack controller **110** may determine which ports of the physical TOR switches **103**, **105** a logical TOR switch command is mapped to via the logical TOR switch model and perform the switch commands on the determined ports of the physical TOR switches **103**, **105**. The method **500** ends at block **508**,

FIG. **6** is a flow diagram depicting an example method **600**. Method **600** may be useful for providing logical racks from inventory in a manner that supports multi-tenancy. The method **600** starts at block **602** and continues to block **604** where a logical rack controller **110** creates logical TOR switches for respective tenants that include mutually exclusive ports of one or more physical TOR switches connected to the plurality of physical computing racks of the inventory. To illustrate, a first logical TOR switch (or a first set of logical TOR switches) may be created from a set of ports of one or more physical TOR switches for a first tenant, and a second logical TOR switch (or a second set of logical TOR switches) may be created from a different, mutually exclusive, set of ports of one or more physical TOR switches for a second tenant. The physical TOR switches from which the logical TOR switches are composed may or may not overlap. In some implementations, the logical rack controller **110** may be multiple cooperating instances (e.g., replica container pods), one instance to manage each logical rack.

At block **606**, the logical rack controller **110** creates logical racks for the respective tenants from mutually exclusive physical infrastructure of the inventory. For example, a computer that is assigned to a first tenant's logical rack is excluded from being assigned to any other tenant's logical rack.

At block **608**, the logical rack controller **110** isolates the logical racks of the respective tenants by defining separate connectivity between the logical racks and logical top of rack switches for corresponding respective tenants. For example, the network connections (e.g., connections between source and destination ports) in a first tenant's logical rack may be placed on a VLAN or VXLAN, and the network connections in a second tenant's logical rack may be placed on a different VLAN or VXLAN. The method **600** ends at block **610**.

FIG. **7** depicts an example system **700** that includes a non-transitory, machine readable medium **704** encoded with example instructions **706**, **708**, **710**, **712** (collectively referred to as instructions **706-712**) executable by a processing resource **702**. In some implementations, the system **700** may be useful for implementing aspects of the logical rack controller **110** of FIG. **1** or for performing blocks of method **200** of FIG. **2**. Similarly, aspects described above with respect to FIGS. **1** and **2** may be applicable to system **700**. Aspects of the instructions described below may be described with reference to elements of FIG. **1** for non-limiting illustration purposes.

The processing resource **702** may include a microcontroller, a microprocessor, central processing unit core(s), an ASIC, an FPGA, an SOC, and/or other hardware device suitable for retrieval and/or execution of instructions from the machine readable medium **704** to perform functions related to various examples. Additionally or alternatively, the processing resource **702** may include or be coupled to electronic circuitry or dedicated logic for performing some or all of the functionality of the instructions described herein.

The machine readable medium **704** may be any medium suitable for storing executable instructions, such as RAM, ROM, EEPROM, flash memory, a hard disk drive, an optical disc, or the like. In some example implementations, the machine readable medium **704** may be a tangible, non-transitory medium. The machine readable medium **704** may be disposed within the system **700**, in which case the executable instructions may be deemed installed or embedded on the system **700**. Alternatively, the machine readable medium **704** may be a portable (e.g., external) storage medium, and may be part of an installation package.

As described further herein below, the machine readable medium **704** may be encoded with a set of executable instructions **706**, **708**, **710**, **712**. It should be understood that part or all of the executable instructions and/or electronic circuits included within one box may, in alternate implementations, be included in a different box shown in the figures or in a different box not shown. Some implementations of the system **700** may include more or fewer instructions than are shown in FIG. **7**.

Instructions **706**, when executed, cause the processing resource **702** to receive an inventory **122** about a plurality of physical computing racks **106**, **108**. The inventory may include computers **102**, **104**, for example. More particularly, the computers may be bare metal servers.

Instructions **708**, when executed, cause the processing resource **702** to receive a logical rack definition **160** that indicates selected physical infrastructure from among the inventory **122** to form a logical rack **112**. For example, the logical rack definition **160** may be based on a predefined specification that indicates the selected physical infrastructure, network visibility of the selected physical infrastructure to the logical rack controller, or application of policy-defined characteristics to the inventory to identify the selected physical infrastructure.

Instructions **710**, when executed, cause the processing resource **702** to validate the logical rack definition **160** by verifying network connectivity of the selected physical infrastructure. For example, instructions **710** may utilize LLDP information to verify network connectivity.

Instructions **712** may be executed after validation of the logical rack definition to cause the processing resource **702** to provide to a provisioning controller **130** an interface **114** to the logical rack **112**. The provisioning controller **130** utilizes the interface **114** to access the logical rack **112** to, for example, perform lifecycle management operations on the physical infrastructure represented by the logical rack **112**.

FIG. **8** depicts an example system **800** that includes a processing resource **802** coupled to a non-transitory, machine readable medium **804** encoded with example instructions. The processing resource **802** and the machine readable medium **804** may be analogous in many respects to the processing resource **702** and the machine readable medium **704**, respectively. In some implementations, the system **800** may be useful for implementing aspects of the logical rack controller **110** of FIG. **1** or for performing blocks of the methods of FIGS. **3-6**. Similarly, aspects described above with respect to FIGS. **1-2** may be applicable to system **800**. Aspects of the instructions described below may be described with reference to elements of FIG. **1** for non-limiting illustration purposes.

The machine readable medium **804** may be encoded with a set of executable instructions **806**, **808**, **810**, **812**, **814**, **816**, **818**, **820**, **822**, **824** (collectively **806-824**). It should be understood that part or all of the executable instructions and/or electronic circuits included within one box may, in alternate implementations, be included in a different box shown in the figures or in a different box not shown. Some implementations of may include more or fewer instructions than are shown in FIG. **8**, In some implementations, one or more of the instructions **806-824** may operate in conjunction or in combination with one or more of the instructions **706-712** described above.

Instructions **806**, when executed, cause the processing resource **802** to receive an updated version of an inventory

122 from an inventory manager **120**. Instructions **8080**, when executed, cause the processing resource **802** to update a logical rack definition **160** by adding new physical infrastructure indicated in the updated version of the inventory **122** to the logical rack definition **160**, removing removed physical infrastructure indicated in the updated version of the inventory **122** from the logical rack definition **160**, or replacing the removed physical infrastructure with the new physical infrastructure in the logical rack definition **160**. Instructions **810**, when executed, cause the processing resource **802** to revalidate the logical rack definition **160** updated by instructions **808**. Revalidation may perform instructions **710** on the updated logical rack definition **160**, for example.

Instructions **812**, when executed, cause the processing resource **802** to receive from the provisioning controller **130** a request to image one or more of the selected physical infrastructure (e.g., computers **102**, **104**) of the logical rack **112**. Instructions **814**, when executed, cause the processing resource **802** to respond to the request by orchestrating a bootstrapping of the one of the selected physical infrastructure to an imaging server **150**.

Instructions **816**, when executed, cause the processing resource **802** to maintain a logical TOR switch **113** that is an abstraction of at least a portion of one or more physical TOR switches **103**, **105**. The physical TOR switches **103**, **105** may be connected to the plurality of physical computing racks in the inventory **122**. Instructions **818**, when executed, cause the processing resource **802** to perform, on the one or more physical TOR switches **103**, **105**, switch commands directed at the logical TOR switch **113** according to the abstraction (i.e., mapping) of the logical TOR switch model. The switch commands may be received from the provisioning controller **130**.

Instructions **820**, when executed, cause the processing resource to create logical top of rack switches for respective tenants that include mutually exclusive ports of one or more physical top of rack switches connected to the plurality of physical computing racks of the inventory. Instructions **822**, when executed, cause the processing resource to create logical racks for the respective tenants from mutually exclusive physical infrastructure of the inventory. Instructions **824**, when executed, cause the processing resource to isolate the logical racks of the respective tenants by defining separate connectivity between the logical racks and logical top of rack switches for corresponding respective tenants.

In the foregoing description, numerous details are set forth to provide an understanding of the subject matter disclosed herein. However, implementation may be practiced without some or all of these details. Other implementations may include modifications, combinations, and variations from the details discussed above. It is intended that the following claims cover such modifications and variations.

What is claimed:

1. A method comprising:

receiving, by a logical rack controller executing on a hardware processing resource, an inventory of a plurality of physical computing racks, wherein the inventory indicates physical infrastructure components;

receiving, by the logical rack controller, a logical rack definition that indicates a selected subset of physical infrastructure components from among the inventory to form a logical rack that is a logical collection of physical infrastructure components organized in a different manner than the physical infrastructure components of the inventory;

validating, by the logical rack controller, the logical rack definition by verifying network connectivity of the selected subset of physical infrastructure components;

after validation of the logical rack definition, providing, by the logical rack controller and to a provisioning controller, an interface to the logical rack, wherein the provisioning controller utilizes the interface to access the logical rack;

maintaining a logical top of rack switch that is an abstraction of at least a portion of one or more physical top of rack switches connected to the plurality of physical computing racks; and

performing, by the logical rack controller and on the one or more physical top of rack switches, switch commands directed to the logical top of rack switch according to the abstraction.

2. The method of claim **1**, further comprising:

receiving an updated version of the inventory from an inventory manager; and

updating, by the logical rack controller, the logical rack definition by:

adding a new physical infrastructure component indicated in the updated version of the inventory to the logical rack definition,

removing a removed physical infrastructure component indicated in the updated version of the inventory from the logical rack definition, or

replacing the removed physical infrastructure component with the new physical infrastructure component in the logical rack definition; and

revalidating the logical rack definition after the updating of the logical rack definition.

3. The method of claim **1**, further comprising:

receiving, by the logical rack controller and from the provisioning controller, a request to image one or more of the selected subset of physical infrastructure components of the logical rack; and

in response to the request, orchestrating bootstrapping of the one of the selected subset of physical infrastructure components to an imaging server.

4. The method of claim **1**, wherein the selected physical infrastructure includes computers, and

the verifying network connectivity includes using link layer discovery protocol information from the one or more physical top of rack switches associated with the logical rack definition to confirm connectivity between the one or more physical top of rack switches and the computers.

5. The method of claim **1**, further comprising:

creating logical top of rack switches, including the logical top of rack switch, for respective tenants that include mutually exclusive ports of one or more physical top of rack switches connected to the plurality of physical computing racks of the inventory;

creating logical racks, including the logical rack, for the respective tenants from mutually exclusive physical infrastructure of the inventory; and

isolating the logical racks of the respective tenants by isolating the respective ports of the respective logical top of rack switches for corresponding respective tenants.

6. The method of claim **1**, wherein the logical rack definition is based on a predefined specification that indicates the selected physical infrastructure, network visibility of the selected physical infrastructure to the logical rack controller, or application of policy-defined characteristics to the inventory to identify the selected physical infrastructure.

7. A non-transitory machine readable medium storing instructions for a logical rack controller that are executable by a hardware processing resource, the instructions for the logical rack controller comprising:

instructions to receive an inventory of a plurality of physical computing racks, wherein the inventory indicates physical infrastructure components;

instructions to receive a logical rack definition that indicates a selected subset of physical infrastructure components from among the inventory to form a logical rack that is a logical collection of physical infrastructure components organized in a different manner than the physical infrastructure components of the inventory;

instructions to validate the logical rack definition by verifying network connectivity of the selected subset of physical infrastructure components;

instructions to provide to a provisioning controller, after validation of the logical rack definition, an interface to the logical rack, wherein the provisioning controller utilizes the interface to access the logical rack to perform lifecycle management operations on the selected subset of physical infrastructure components in the logical rack;

instructions to maintain a logical top of rack switch that is an abstraction of at least a portion of one or more physical top of rack switches connected to the plurality of physical computing racks; and

instructions to perform, on the one or more physical top of rack switches, switch commands directed to the logical top of rack switch according to the abstraction.

8. The non-transitory machine readable medium of claim **7**, wherein the instructions for the logical rack controller further comprise:

instructions to receive an updated version of the inventory from an inventory manager; and

instructions to update the logical rack definition by:

adding new a physical infrastructure component indicated in the updated version of the inventory to the logical rack definition,

removing a removed physical infrastructure component indicated in the updated version of the inventory from the logical rack definition, or

replacing the removed physical infrastructure component with the new physical infrastructure component in the logical rack definition; and

instructions to revalidate the logical rack definition after the logical rack definition is updated.

9. The non-transitory machine readable medium of claim **7**, wherein the instructions for the logical rack controller further comprise:

instructions to receive from the provisioning controller a request to image one or more of the selected subset of physical infrastructure components of the logical rack; and

instructions to respond to the request by orchestrating a bootstrapping of the one of the selected subset of physical infrastructure components to an imaging server.

10. The non-transitory machine readable medium of claim **7**, wherein the selected physical infrastructure includes computers, and

the instructions to validate the logical rack definition includes using link layer discovery protocol information from the one or more physical top of rack switches associated with the logical rack definition to confirm connectivity between the one or more physical top of rack switches and the computers.

11. The non-transitory machine readable medium of claim **7**, wherein the instructions for the logical rack controller further comprise:

instructions to create logical top of rack switches, including the logical top of rack switch, for respective tenants that include mutually exclusive ports of the one or more physical top of rack switches connected to the plurality of physical computing racks of the inventory;

instructions to create logical racks, including the logical rack, for the respective tenants from mutually exclusive physical infrastructure of the inventory; and

instructions to isolate the logical racks of the respective tenants by isolating the respective ports of the respective logical top of rack switches for corresponding respective tenants.

12. The non-transitory machine readable medium of claim **7**, wherein the logical rack definition is based on a predefined specification that indicates the selected physical infrastructure, network visibility of the selected physical infrastructure to the logical rack controller, or application of policy-defined characteristics to the inventory to identify the selected physical infrastructure.

13. A system comprising:

a processing resource; and

a non-transitory machine readable medium storing instructions for a logical rack controller that, when executed, cause the processing resource to:

receive an inventory of a plurality of physical computing racks, wherein the inventory indicates physical infrastructure components;

receive a logical rack definition that indicates a selected subset of physical infrastructure components from among the inventory to form a logical rack that is a logical collection of physical infrastructure components organized in a different manner than the physical infrastructure components of the inventory;

validate the logical rack definition by verifying network connectivity of the selected subset of physical infrastructure components;

provide to a provisioning controller, after validation of the logical rack definition, an interface to the logical rack, wherein the provisioning controller utilizes the interface to access the logical rack;

maintain a logical top of rack switch that is an abstraction of at least a portion of one or more physical top of rack switches connected to the plurality of physical computing racks; and

perform, on the one or more physical top of rack switches, switch commands directed to the logical top of rack switch according to the abstraction.

14. The system of claim **13**, wherein the instructions, when executed, cause the processing resource to:

receive an updated version of the inventory from an inventory manager; and

update the logical rack definition by:

adding a new physical infrastructure component indicated in the updated version of the inventory to the logical rack definition,

removing a removed physical infrastructure component indicated in the updated version of the inventory from the logical rack definition, or

replacing the removed physical infrastructure component with the new physical infrastructure component in the logical rack definition; and revalidate the logical rack definition after the logical rack definition is updated.

15. The system of claim **13**, wherein the selected physical infrastructure includes computers, and

the instructions that cause the processing resource to validate the logical rack definition includes instructions to use link layer discovery protocol information from the one or more physical top of rack switches associated with the logical rack definition to confirm connectivity between the one or more physical top of rack switches and the computers.

16. The system of claim **13**, wherein the instructions, when executed, cause the processing resource to:

create logical top of rack switches, including the logical top of rack switch, for respective tenants that include mutually exclusive ports of one or more physical top of rack switches connected to the plurality of physical computing racks of the inventory;

create logical racks, including the logical rack, for the respective tenants from mutually exclusive physical infrastructure of the inventory; and

isolate the logical racks of the respective tenants by isolating the respective ports of the respective logical top of rack switches for corresponding respective tenants.

17. The system of claim **13**, wherein the logical rack definition is based on a predefined specification that indicates the selected physical infrastructure, network visibility of the selected physical infrastructure to the logical rack controller, or application of policy-defined characteristics to the inventory to identify the selected physical infrastructure.

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